Chemical Control of Plant Growth

U.S. DEPARTMENT OF AGRICULTURE Science Study Aid No.—7

TEACHER'S INTRODUCTION

This Science Study Aid contains seven experiments. They are intended to help students investigate the control of plant growth with chemicals. Most of the materials needed can be found at home or in school. Those which must be purchased can usually be found locally.

The subject matter of this Science Study Aid is divided into three broad topics: (1) plant growth regulators, (2) weed control, and (3) chemical pruning. Each topic is subdivided into two or three individual experiments. These experiments are based on investigations that have been and are being conducted at the U.S. Agricultural Research Center, Beltsville, Md.

Although it would be beneficial to study all three topics, each one is independent and can be investigated as a separate activity.

Chemical Control of Plant Growth was developed by science teachers working with the research staff at the U.S. Agricultural Research Center, Beltsville, Md. The experiments in this Science Study Aid have been tested in the laboratory and in the classrooms of cooperating teachers.

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VOCABULARY

active ingredient—the chemical element or compound in a product that is responsible for its effects.

annual—a plant that completes its life cycle in one year.

biennial—a plant that completes its life cycle in two years. The first year it produces leaves and stores food. The second year it produces fruits and seeds.

carrier—the liquid or solid material added to a chemical compound to facilitate application to whatever is being treated.

chemical name—a name that indicates the composition of the compound and also the structure of the molecule in organic compounds.

concentration—the amount of active ingredient in a given volume of liquid or in a given weight of dry material.

diluent—any liquid or solid material used in the preparation of a formula to dilute the active ingredient.

growth regulator—an organic substance that is effective, normally in minute amounts, in controlling or modifying plant processes.

herbicide—a phytotoxic chemical used for killing or inhibiting the growth of certain plants.

herbicide-resistant species—one that is difficult to kill.

perennial—a plant that lives more than 2 years.

petioles—leaf stalks.

petri dish—a small, shallow container of thin glass with a loosely fitting cover for plate culture in bacteriology.

phytotoxic—poisonous to plants.

rate—the amount of active ingredient or acid-equivalent of a herbicide or growth regulator applied to a given area.

soil application—application of herbicide made primarily to the soil surface rather than to vegetation.

solvent—the component of a solution that dissolves the other components.

toxicology—a science that deals with poisons and their effect on living organisms, with substances otherwise harmless that prove toxic under particular conditions, and with the clinical, industrial, legal, or other problems involved.

weed—a plant growing where it is not desired.

PRECAUTIONS

All chemicals described in this publication should be applied in accordance with directions on the manufacturer's label, as registered under the Federal Insecticide, Fungicide, and Rodenticide Act. Specifications with respect to crop, amount of chemical, and time of application should be strictly observed.

All chemical pesticides are toxic to some form of life. Their very toxicity is the basis for their action. The relative toxicity of a pesticide is determined by testing it with laboratory animals such as rats. The animals are exposed to varying levels of the pesticide by different routes of administration. The amount of the pesticide that causes 50 percent of the test animals to die is known as LD_{50} of the pesticide. The LD_{50} of the pesticide to the test animal is expressed in milligrams per kilogram body weight and also as acute oral, dermal or respiratory, representing the route of administration. The lower the numerical LD_{50} the greater the toxicity to the laboratory animal tested.

Relatively toxic pesticides, as measured by animal experiments, can be used in pest control programs when the amounts and directions for use indicated on the label are followed. None of the chemicals used in the experiments described in this Science Study Aid are either highly or moderately toxic to laboratory animals. These chemicals can be used in these experiments with little or no hazard to the participants.

The following general precautions should be observed in applying pesticides (herbicides and growth regulators) discussed in this SSA:

1. Read the label on each container before using the contents. Follow instructions; heed all cautions and warnings. Store in closed, well-labeled containers out of

reach of small children and pets, and where the pesticides cannot contaminate food or water.

2. Avoid inhaling vapors, dusts, or spray mists. Use a mask when specified on the container label.
3. Avoid repeated or prolonged contact of pesticides with the skin. Some individuals are hypersensitive to certain chemicals and must be especially careful to avoid allergic reactions.
4. Wash hands and face thoroughly with soap and water after each use of a pesticide. Do not eat, drink, or smoke until you have washed your hands and face. Wear synthetic rubber gloves and wear goggles where label instructions specify.
5. Avoid spilling pesticide concentrate on your skin and keep it out of your eyes, nose, and mouth. If you spill any on your skin, wash it off immediately with soap and water. If you spill it on your clothing, launder the clothing before wearing it again.
6. Handle flammable chemicals with care to avoid ignition from friction, sparks, or contact with combustible materials.
7. Avoid contaminating potable water supplies (as in wells) with pesticides.
8. Order only the amount of pesticide you will need for an experiment. Companies normally supply larger amounts than that needed for a few experiments and the large amounts they package are relatively inexpensive. Therefore, try to arrange orders for pesticides through the purchasing agent for your school. In this way, one inexpensive order can serve several classes and provide enough chemical for many experiments.
9. After you have used up the pesticide you ordered, wrap the empty container in sheets of newspaper and put it in a plastic bag. Place this bundle in a brown paper bag and dispose of it in a trash container.
10. To dispose of a liquid pesticide solution, dissolve a double portion of plain gelatin in the liquid. The liquid can be at room temperature. Add more gelatin, if necessary, to hasten the solidifying process. Then dispose of the solid materials as directed in step 9.
11. Avoid spraying pesticides on plants other than those you are testing, or plants that might come within reach of children or animals. Also, do not allow herbicides to get into open water where they might become available to pets, wildlife, or livestock.
12. Do not use pesticide application equipment for any other purpose. When the experiments are completed, discard the applicators.

EXPERIMENTS WITH PLANT GROWTH REGULATORS

Scientists of the Agricultural Research Service, United States Department of Agriculture, are pioneering a new era in agriculture. It is the dream of these scientists that some day they will be able to control plant growth as readily as we now control electricity. They are finding, through extensive research, that certain chemical substances can tell plants how or when to grow, to bloom, or to produce seeds. It may turn out that nearly all functions of plants are chemically controlled.

Discoveries made so far have led to experiments in which chemicals are applied to plants in an attempt to regulate the patterns of plant growth. Now, after a decade of testing and retesting, scientists have come up with some very promising plant-growth regulators. They have discovered chemicals that will inhibit growth, stimulate growth, prevent blooming, and induce blooming.

This research was begun in response to the demands of the buying public for shorter plants, for faster growing trees, for flowers that bloom at a particular time of the year, and for other new types of plants. Although our scientists

have gained some control over particular growth factors, there is still much to be learned before we achieve total chemical control over plants.

The following three activities are but a few examples of how a student can experiment with plant-growth regulators. These experiments are conducted primarily on beans, but the results can be applied to many other plants. Bean plants provide the researcher with test organisms that are readily available, easy to grow, and quick to respond to the chemicals being used.

Read all the directions carefully before beginning the experiments. After conducting these experiments as directed, you may wish to make other, related investigations that will help you to formulate new ideas about growth regulators.

EXPERIMENT I:
Using Gibberellic Acid to Stimulate Plant Growth

Several years ago, research scientists in Japan noticed that a compound derived from Asian fungus *Gibberella fujikuroi* caused stem lengthening in several plants. Since then, scientists have accumulated enough knowledge about gibberellic acid to make it usable by farmers and home gardeners. This chemical is now produced commercially as a plant stimulator.

Objective:

To determine the effects of gibberellic acid[1] on the development of plants by treating several plants with the chemical and comparing their growth with that of control plants.

Materials:

1. At least ten 4-inch flower pots or similar containers.
2. Potting soil or vermiculite.
3. Gibberellic acid (a list of suppliers is enclosed).
4. Baby shampoo (to serve as a wetting agent).
5. Bean seeds (any species will work, but several different species may be used for comparison).

Procedure:

1. Recording data: Obtain a notebook and record all of your data, such as planting schedule, chemical application schedule, and, most important, comprehensive reports of your results.
2. Planting: Plant the beans in the 4-inch pots or similar containers about 1/2 to 1 inch beneath the surface of the soil. After the beans are planted, mark the pots to show whether they contain test plants or control plants. This will save confusion later when you apply the chemical. You may wish to treat half the plants and use the other half as controls for comparison. If you want to make different applications of the chemical, you could use nine plants: three for one treatment, three for another treatment, and three as control plants.
3. Light and temperature: Keep your pots with planted seeds where they will be well lighted. A temperature of 80° to 85° F. is best for germination of bean seeds. Keep the plants moist throughout the experiment. If these conditions are met, the plants should be up in about 4 to 5 days; if the temperature is lower, germination may be slower.
4. Mixing gibberellic acid solution: Solutions made from a commercial formula should be mixed according to the manufacturer's directions. If crystalline powder gibberellic acid is used, follow this procedure:
   a. Dissolve 1 gram of powder in 5 milliliters of 95 percent ethyl alcohol. This will give you a basic concentrate.
   b. Add 1 milliliter of baby shampoo.
   c. Add the concentrated mixture to 1 liter of warm water. This preparation contains 1,000 p.p.m. of gibberellic acid.
5. Treating the test plants: When the plants are 8 to 10 days old, treat the test plant by spraying the solution of gibberellic acid, as prepared, on the stems and leaves. Use a (bulb-type) hand sprayer for this procedure. Be careful not to spray the control plants. If conditions are right (that is if light, heat, and moisture are normal as described in 3 above) most young plants will show some response within 24 hours.
6. Treating the control plants: Spray control plants with a solution of 1 milliliter of baby shampoo in 1 liter of water. Use a different (bulb-type) hand sprayer.
7. Length of the experiment: This experi-

[1] According to the American Pharmaceutical Association Journal, vol. 48, No. 2, February 1959, pp. 127-130, when gibberellic acid was administered to mice orally at 15 grams per kilogram of body weight, no deaths occurred. The article said, in summary, that the "gibberellic acid was tested by various routes in mice for its acute toxicity and found to be essentially nontoxic."

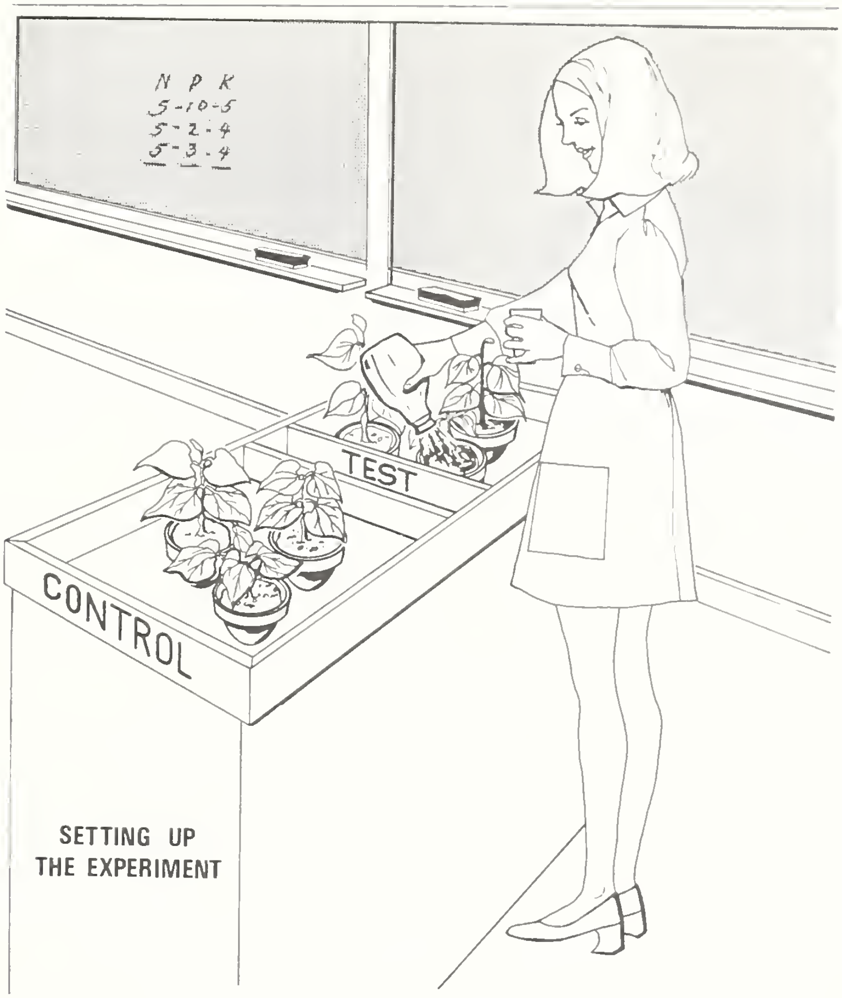

Figure 1 - Test plants and control plants are needed for each chemical treatment. Tag each plant so that it can be marked and identified during and after treatment.

ment can end 20 days or less after the beans are planted. By that time, the test plants should exhibit observable effects of gibberellic acid treatment.

Results:

1. Compare the leaves of the control plants with the leaves of the test plants. Note any differences in color.
2. Compare the leaf size of the controls and the test plants.
3. Compare the height of controls and the test plants to determine the effect of gibberellic acid on the growth of beans.
4. As a last step in your experiment, remove all the plants from their pots or containers, shake loose or wash away the soil or vermiculite, and examine the roots of the test and control plants. Observe whether the treatment had an effect on root size.

Interpretation:

What can we conclude from the treatment of bean plants with gibberellic acid? What parts of the plant were changed? How might chemical regulators in general, and gibberellic acid in particular, be used in agriculture? Can you devise other experiments to investigate the effect of gibberellic acid on plants other than beans?

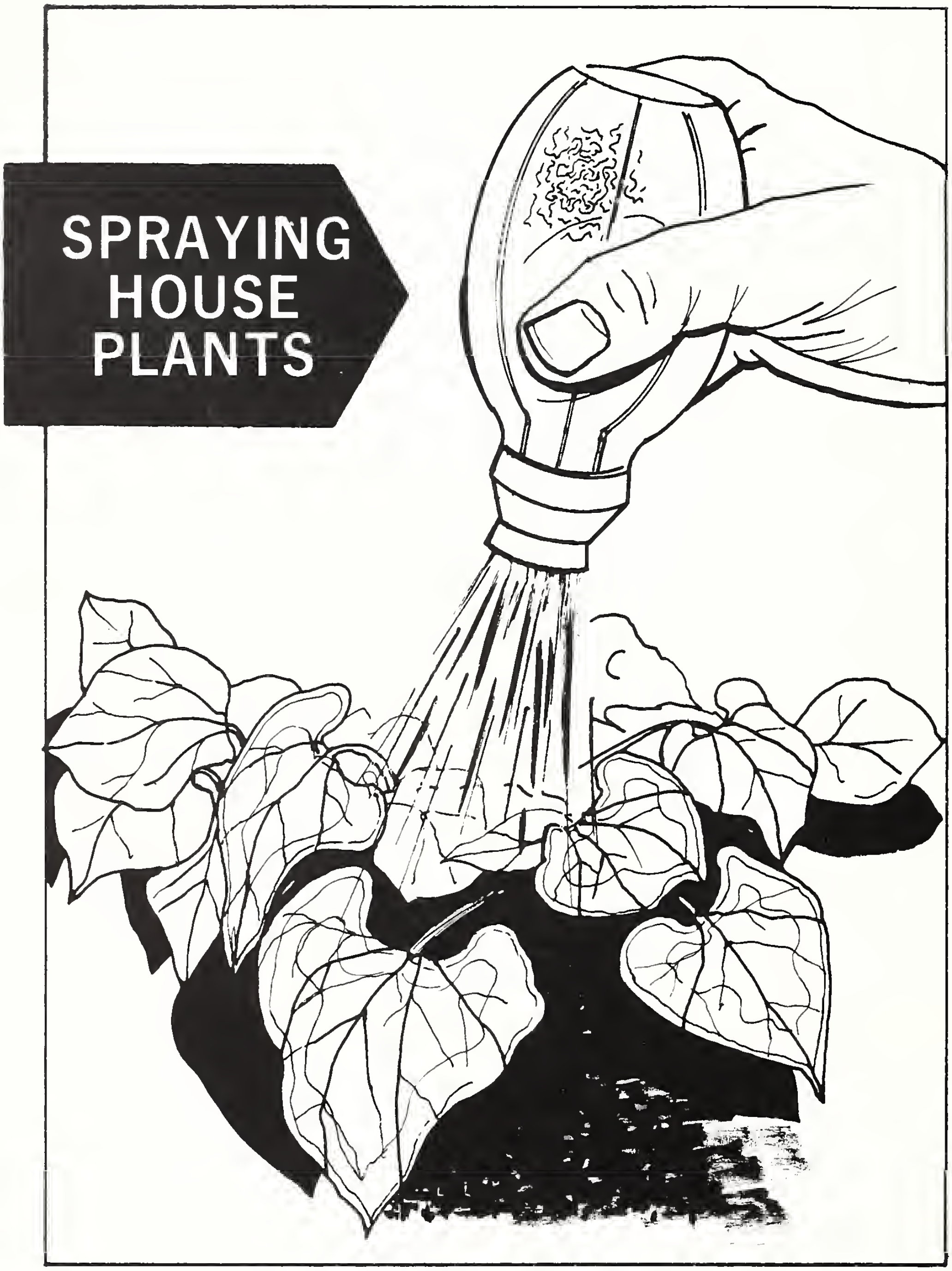

Figure 2 - A bulb-type hand sprayer is used to spray gibberelic acid on the stems and leaves of a test plant.

EXPERIMENT II:
Using MH-30 to Prevent Sprouting

Chemical regulators may be used to either stimulate or retard the growth of plants. Research scientists are experimenting with certain plant-growth retardants to prevent sprouting of stored products, particularly carrots, potatoes, and onions. Unwanted sprouting of these vegetables causes considerable cash loss to farmers, home gardeners, and wholesalers. The sprouts reduce the market price, and shorten the storage life of the vegetables, and may quickly make them unmarketable.

Scientists believe that a suitable chemical that will prevent sprouting might be sprayed on vegetables at the time they go into storage to prevent present market losses and thus help to reduce the cost of vegetables to consumers. Most sprout-inhibiting chemicals are still in the experimental stage. MH-30 is approved for use on potatoes and onions. This research should prove valuable to commercial growers, food marketers, and homemakers.

In the following experiment you can investigate the effect of the chemical MH-30[2] on the sprouting of carrots, potatoes, and onions, which are stored in the dark. These three vegetables often present a premature sprouting problem. Many housewives have gone to their storage bins to find that their potatoes or onions have long sprouts and are no longer usable.

MH-30 and other chemicals are being used experimentally to improve the storage life of fruits and certain vegetables. This work is a good example of how basic research can lead to practical advantages.

Objective:

To determine the effectiveness of MH-30 in retarding vegetable sprouts by comparing the development of plants treated with the chemical to that of untreated plants.

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[2] Diethanolamine salt of 6-hydroxy-3-(2H)-pyridazinone.

Materials:

1. A cutting spoon used to cut balls from melons.
2. Sphagnum moss or fine quartz sand.
3. Petri dishes or other shallow containers about 10 cm. in diameter.
4. A dark room where the temperature is about 65° to 70° F.
5. A cold storage area with a temperature of 40° to 50° F.
6. Three grams of MH-30. (See list of sources on page 20.)
7. Unsprouted vegetables, such as carrots, onions, or potatoes, which have experienced a rest period (see "Procedure").

Procedure:

1. Preparation of vegetables.
   a. *Carrots* - Select medium-sized carrots for uniformity. Sever petioles so that about 1 cm. of each petiole remains attached to each root. Remove and discard the lower part of the root from each carrot, saving about 1 inch of the upper part. Place these pieces in humid air at 40° to 50° F. for about 3 to 4 days until they become suberose (the exposed bottom of the stub becomes callused).
   b. *Onions* - Select small onions about 1 to 2 cm. in diameter and of uniform shape. When you are ready to lay them in the moss or sand, peel the outer, loose scales from the bulb.
   c. *Potatoes* - Select tubers of medium size. Using a cutting spoon, remove spherical pieces from the tubers so that each piece contains one eye. Place the pieces in humid air at 40° to 50° F. for several days until they become suberose.

NOTE: Prepare about 20 to 25 pieces of each vegetable so you have enough for both your test plants and your control plants. Prepare the carrots and potatoes and allow them to suberize before peeling the onions.

2. Mixing the MH-30 solution: Prepare your solution by mixing 1 milliliter or milligram of MH-30 in 1 liter of tap-water. (If you do not have a scale for measuring out milligrams, mix 1 part of MH-30 to 29 parts of water. For additional information, see directions on MH-30 container.)
3. Treatment: Select 10 of each prepared vegetable for your test plants. Dip them momentarily into the MH-30 solution. Allow to drain. Place the treated pieces on the moist sphagnum moss or sand that you have placed in the petri dishes. Do not cover the dishes.
4. Control Plants: Prepare 10 additional vegetable pieces as control plants by dipping them in water only and then placing them in petri dishes, as you did the test plants.
5. Storage: Place all of the dishes in a darkened room with a temperature of about 65° to 70° F. Keep the moss or sand moist.
6. Method of checking results: After the control plants have developed a measurable amount of new vegetable growth, measure the length of the stem (sprout) and the fresh weight of the detached sprouts. Compare these measurements with similar ones for the treated materials. Record all of this information. For variations on this experiment, the following is suggested:
   a. Leave some control and treated plants in a lighted room for comparison.
   b. Test the experiment under different temperatures by placing some of the dishes in a warmer or colder place.

Interpretation:

Discuss the importance of this experiment in terms of the grower, the food store owner, and the homemaker. Discuss how MH-30 could affect the cost of vegetables in the future. After you have been successful in this experiment, you may wish to test other species of plants.

EXPERIMENT III:
Using Amo 1618 to Inhibit Plant Growth

The agricultural use of chemicals as growth inhibitors is becoming more important. They inhibit stem growth of a plant, or stop its growth at a desired height. Research in this area is in answer to increasing demands for more compact plants by crop growers, home gardeners, and flower buyers.

Tall crop plants, ornamentals, sky-reaching shade trees, and shrubs that need frequent trimming and pruning, are common problems that growers would like to overcome. The effort to find scientific solutions to such problems has looked promising since 1949. It was then that plant scientists of USDA's Agricultural Research Service first reported organic chemicals that would dwarf a test plant without harm to the plant.

Although many different plant-shortening compounds have been tested, the following experiment deals with only one, Amo 1618[3], applied to a particular plant, beans.

Objectives:

To determine the effects of Amo 1618 on bean plants by comparing the development of treated and untreated seedlings.

Materials:

1. Twenty or more 4-inch flower pots or similar containers. (More pots may be used, but 20 is sufficient for good results.)
2. Potting soil or vermiculite.
3. Disposable wood applicators, such as toothpicks.
4. 300 mg. of Amo 1618. (See list of sources on page 20.)
5. A liquid dish-washing detergent containing polyoxethylene sorbitan monoluarate.
6. Lanolin paste solution. (See item 4 under "Procedure.")
7. Bean seeds. (Any species will do for this experiment.)

[3] 1-piperidine-carboxylate.

Procedure:

1. Recording data: Record all of your data, such as planting schedule, chemical application schedule, and, most important, a comprehensive record of your results.
2. Planting: Plant the beans in the 4-inch flower pots or similar containers about 1/2 to 1 inch below the surface of the soil. Water after planting and keep the soil moist to the touch.
3. Light and temperature: Keep the potted plants in a place where they are well lighted. A temperature of 80° to 85° F. is best to germinate the bean seeds. If light, heat, and moisture conditions are right, the seeds should germinate in 4 or 5 days. If the temperature is lower, germination will be slower.
4. Mixing Amo 1618 paste: To prepare a 1 percent mixture of Amo-1618, place 25 mg. of the chemical in a vial or test tube and add 14 drops of the detergent. (If you do not have a scale for measuring out 25 milligrams, see directions on Amo-1618 container.) Stir to dissolve the chemical and then add 2 grams of lanolin. (Lanolin can be purchased at drugstores.) Melt the lanolin by putting the test tube in warm water (not warmer than 131° F. or 55° C.) for a few minutes. Remove the test tube and stir the mixture until it reaches room temperature and becomes semisolid. The paste is now ready for use.
5. Application: First allow all plants (test and control) to grow for 10 days. On the 10th day, pair off the plants according to size, putting similar sized plants together. Now is the time to mark and number your test and control plants. One way of marking is to put black tape on the control plants and red tape on the test plants. With a wood applicator, apply the paste in a band 3 to 6 mm. wide around the stem at the first internode—midway between the first and second nodes—of each red-taped (test) bean plant in each pair.

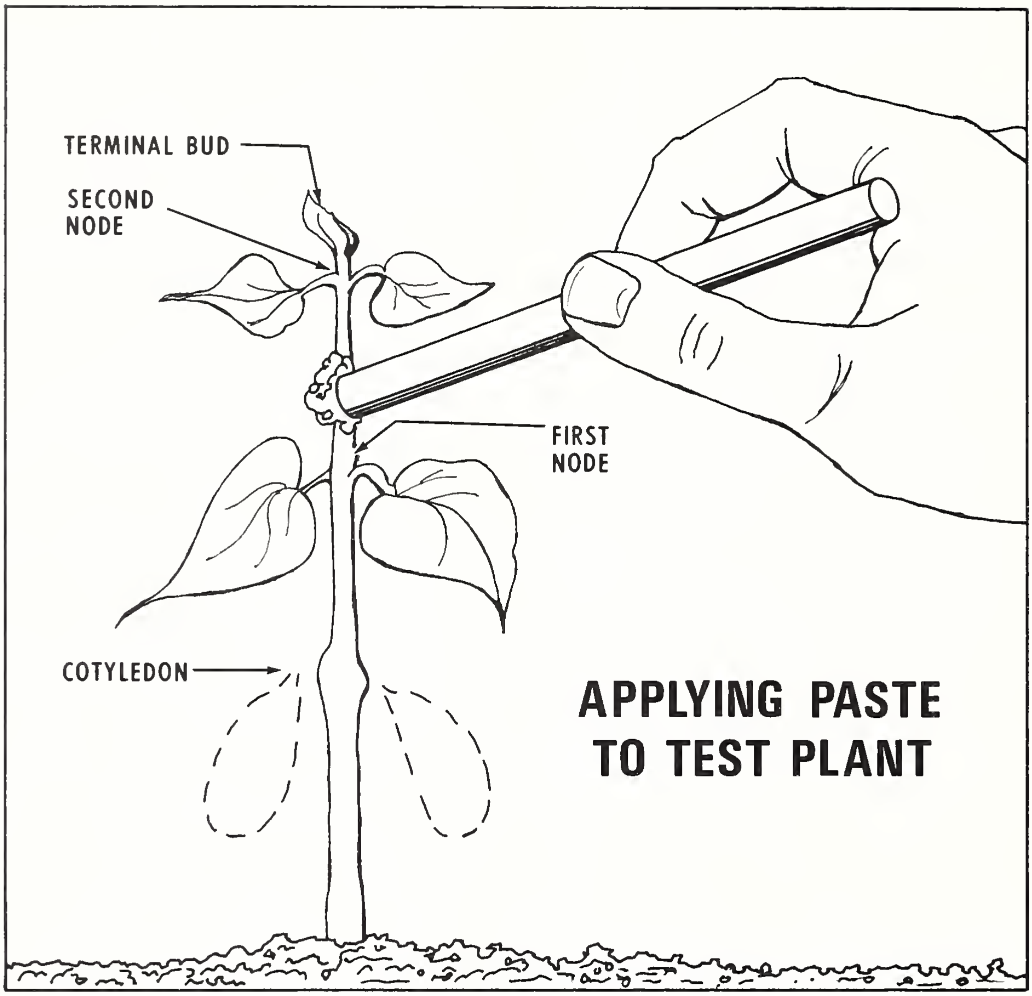

Figure 3 - A wood applicator is used to apply paste around the first internode - midway between the first and second nodes - of each test bean plant.

6. Allow all the plants to grow for an additional 7 to 12 days.

Results and Comparisons:

1. To determine the effect of Amo-1618 on bean plants, measure at time of application and again one week later. To do this, place a ruler at the node immediately above the treated section of the stem. Then measure the distance from this node to the tip of the terminal bud.
2. Measure the untreated (control) plants in the same way.
3. During the test, note any differences in the shape of leaves, stems, or other plant parts. You may find changes in color and other modifications that have occurred because of the treatment.

Interpretation:

What is the importance of growth regulating chemicals for food production? What desirable effects can the use of Amo-1618 bring about in plants? What hazards could it possibly create in the life cycle of a plant? For further investigation into the use of Amo-1618, conduct the same test on other plants, such as sunflowers and cucumbers.

EXPERIMENTS IN WEED CONTROL

A weed is a plant growing where it is not wanted. Man's struggle with weeds is as old as man himself. Weeds are persistent, and often prolific. They reduce crop yields, increase labor production costs, and interfere with efforts to grow food and flowers.

No part of man's food supply is immune to the adverse effects of weeds. Production of food for man by marine life, wild animals, domestic animals, field crops, vegetable plants, wild plants, and other sources may be significantly affected by weeds. Weeds compete with crops for minerals, water, light, and essential nutrients. They may interfere with crop harvesting.

Man continues to suffer serious economic losses from weeds despite many cultural, mechanical, and biological control measures at his disposal. Because of the need for more efficient control methods, the use of chemicals for weed control has grown rapidly since 1945.

New herbicides are developed by both Government and industrial scientists, quite often in joint projects. Before a herbicide is released by the United States Department of Agriculture for public use, it is tested repeatedly for its usefulness and safety in relation to plants, animals, and man. To prevent the pollution of our valuable soil resources, the Department conducts tests to determine what happens to these herbicides after they enter the soil. The cost of testing and developing a single formula usually runs between 5 and 7 million dollars.

Cultural, biological, and chemical weed control is essential to efficient food production. The development of sound weed control practices requires the cooperative effort of many research disciplines.

These disciplines include the fields of organic chemistry, biochemistry, plant physiology, agronomy, horticulture, aquatic biology, ecology, agricultural engineering, analytical chemistry, microbiology, soil science, biometrics, and animal physiology. Through knowledge gained in these fields of study, man may some day win the struggle against weeds.

EXPERIMENT IV:
Killing Weeds With Chemicals

Certain chemicals can kill one plant and yet be harmless to another. Hence, we can spray certain vegetable crops to destroy the weeds around them without injuring the crop itself. In the following experiment, beans will represent the vegetable crop and ryegrass the weed.

Objective:

To determine whether a certain chemical is selective in killing weed-grasses by applying the chemical to flats planted with two different kinds of plants and comparing development to untreated plants.

Materials:

1. Three wooden greenhouse flats (boxes) about 18 inches by 24 inches and 4 to 6 inches deep.
2. Potting soil or a mixture of soil and vermiculite.
3. One 1-gallon jug with a cap.
4. Bean seeds and ryegrass seeds.
5. Herbicide containing trifluralin.
6. Rubber bulb-type hand sprinkler.
7. Graduated 50 ml. cylinder.

Procedure:

1. Fill three greenhouse flats with soil and label the flats A, B, and C.
2. Plant a row of beans across the length of each flat 1 to 1-1/2 inches deep. Sprinkle the ryegrass over the remainder of the flat and carefully work the grass seed into the top 1/2 inch of soil.
3. Prepare a trifluralin concentrate by measuring 6 ml. of trifluralin solution into a gallon jug. Add water to fill the bottle and shake vigorously.
4. Flat A is the control flat. Sprinkle, as needed, with water only—do not use trifluralin on this flat.
5. Flat B will represent the proper application of herbicide on vegetable crops. In the 50 ml. cylinder, mix 12.5 ml. of trifluralin concentrate from the jug with 37.5 ml. of water. Using the rubber bulb-type hand sprinkler, apply 50 ml. of this diluted concentrate to each square foot of soil surface. This amount is equivalent to applying the chemical at 1 lb. per acre. If the same bulb is used to apply both concentrations, (see item 6), the lower concentration should be applied first.
6. Flat C will represent over-application of herbicides. Apply 50 ml. of the trifluralin concentrate to each square foot of soil surface. This amount is equivalent to applying the chemical at 4 lb. per acre.
7. In applying the herbicide concentration, use the bulb-type sprinkler to spray the solution uniformly over the soil surface. Be sure to wash the sprinkler several times after using it to attempt to remove all traces of the herbicide.
8. Cover the treated area in the three flats with about 1/4-inch of finely sifted potting soil. Water by gently sprinkling the surface whenever the soil needs moistening. Beans in the flats should germinate in about 4 to 6 days. The ryegrass in Flat A should come up at about the same time.

Results and Comparisons:

1. Measure and compare the growth of beans in each of the three flats.
2. Measure and compare the growth of the ryegrass in each of the three flats.
3. Observe and determine which flat shows competition between the beans and the ryegrass.

Interpretation:

Define a herbicide. Explain what desirable effects can be brought about with the proper use of herbicides. What undesirable effects can result from improper use: After you have been successful in this experiment, test the herbicide on other species of plants.

EXPERIMENT V:
Gentner Herbicide Evaluation Method

Dr. W. A. Gentner of the Agricultural Research Service has developed a simple method of testing a variety of plants and herbicides by using test tubes instead of flower pots or conventional containers. This technique enabled him to study many plants at one time and to watch the progress of each plant more closely.

Objective:

To compare the effects of various herbicides and various concentrations of herbicides on five different types of plants in test tubes.

Materials:

1. Test tubes or funnels (5 for each seed tested).
2. Drill, 1/4-inch, with sanding disc (optional).
3. Glass wool (angel hair).
4. Goggles, protective (optional).
5. Quartz sand.
6. Respirator (optional).
7. Rubber collars (or some similar device) to hold test tubes or funnels above beakers.
8. Beakers (5 for each seed tested).
9. Nutrient solution. (Any liquid plant food purchased at a local supply shop will be sufficient. Follow the manufacturer's directions.)
10. Herbicides to be tested—for example, trifluralin, atrazine, diuron, molinate. These chemical names will appear in the statement of active ingredients on the label.
11. Ryegrass, corn, lettuce, mustard, and radish seeds.

Procedure:

1. Set up five test tubes or funnels for each plant species you plan to use. Four will be experimental and one will serve as a control. If test tubes are used, rub the bottom of each tube with a sanding disc on 1/4-inch drill until a small hole forms. This process takes time and patience. For safety, use a respirator and goggles.
2. Mix the nutrient you will use as a test solution. To this, add a concentration of the herbicide to be tested. Use concentrations ranging from 0.1 p.p.m. to 5.0 p.p.m. (See step 6, below.)
3. Place rubber collars (or similar devices) to hold test tubes above the beakers. If funnels are used, put them in rings, attach to ringstand, and place over beakers.
4. Place 3/4-inch wads of glass wool (angel hair) in bottom of test tubes or funnels. This wad will keep the sand from flowing through the base hole of the test tube or funnel.
5. Half fill the test tubes or funnels with clear quartz sand.
6. Place nutrient solution and different concentrations of herbicides in four of the beakers. In the fifth beaker, add only the nutrient solution. Be sure to mark each beaker properly.
7. Plant two or three seeds 1/4-inch deep in the sand of all test tubes or funnels.
8. Suspend the test tubes or funnels over the beakers containing solutions to be studied. Once a day, immerse the tubes or funnels into the solution so as to saturate the quartz sand. Raise the tubes or funnels after saturation so that they do not contact solutions in beakers.
9. Record all data about the plants including growth rate, shape of leaves, length of stems and roots, and concentration of herbicides.

Interpretation:

What differences did you observe between experimental and control plants? How can this experiment be useful to industry? How can this experiment be important to the farmer and home gardener? Continue your research by exposing more plants to different herbicides. Also, test different concentrations of herbicides to find the safest levels of herbicides tolerated by each test species.

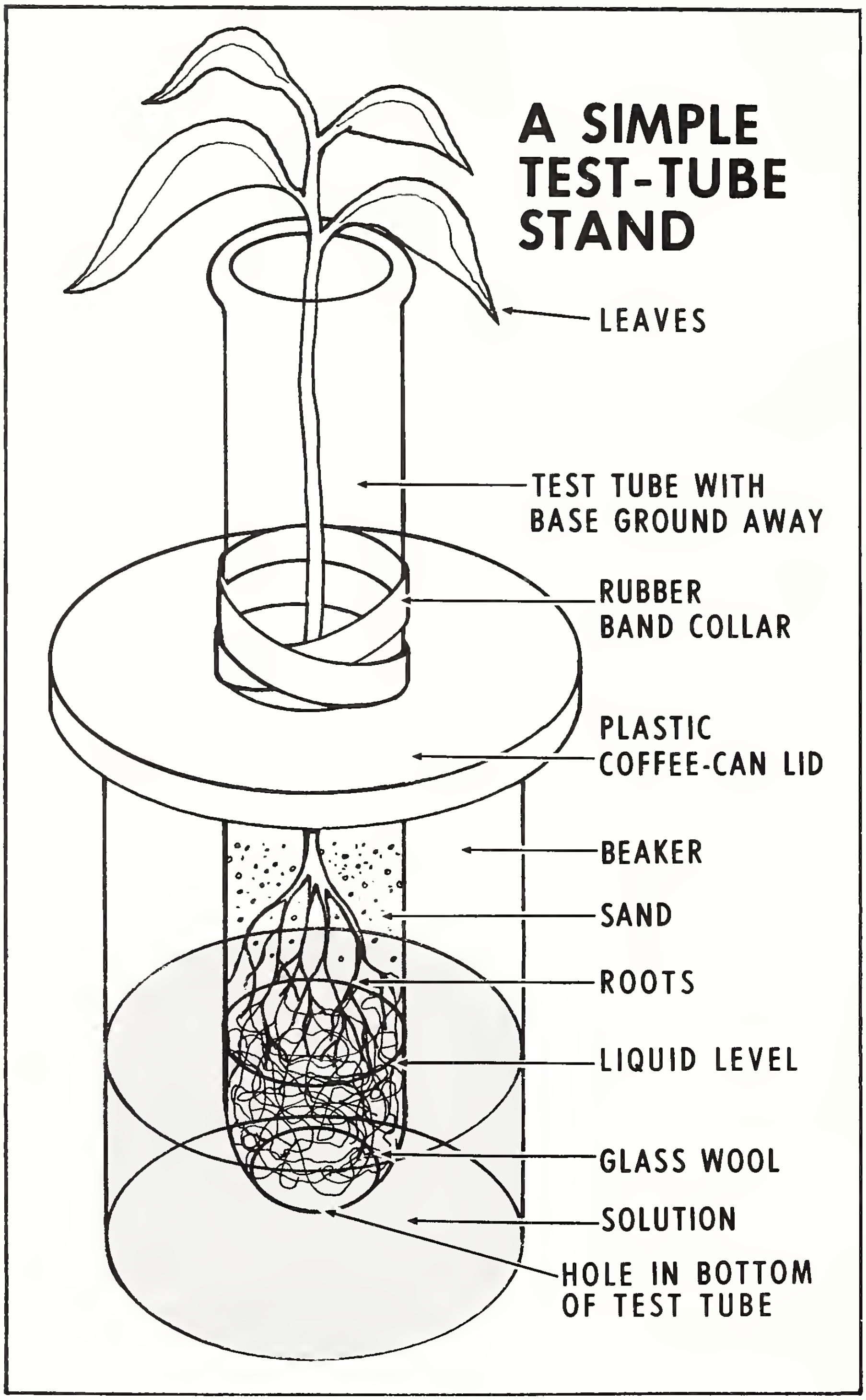

Figure 4 - A simple test tube stand.

EXPERIMENTS IN CHEMICAL PRUNING

In many areas, the lack of garden space has become a problem for the amateur horticulturist. People live in crowded conditions where wastes often pollute the air and soil. Green, growing things have a difficult time.

Trees grow too high and shrubs spread out too much for an apartment balcony or even a small yard. Horticulturists are conducting experiments on chemical pruning which may help to solve this space problem.

Chemical pruning means that certain plants and trees can be sprayed with a chemical to control their size. Eventually, even with the smallest yard or garden box, we will be able to enjoy the surroundings created by growing trees and shrubs. So far, however, chemical pruning is still in the experimental stage. Extensive research remains to be done before pruning chemicals are released to the public.

EXPERIMENT VI:
Pruning Trees and Shrubs

The following experiment will allow a student researcher to conduct some basic study with pruning chemicals either at his home or at school. Please read all directions carefully before starting the experiment. The experiment requires at least 6 weeks to complete and the chemical kits must be ordered in advance.

Objective:

To compare the effects of various concentrations of chemical pruning agent on different types of trees and shrubs.

Materials:

1. Chemical pruning agent kit, which can be ordered from either of the following addresses:

   Emery Industries, Inc.
   4300 Carew Tower
   Cincinnati, Ohio 45202

   Proctor & Gamble Industrial Soap
   & Chemical Products Division
   Cincinnati, Ohio 54217

2. Waterproof tags and magic marker.
3. A throat atomizer or similar device with which you can spray a fine mist on your test plants.
4. Two pieces (for each tree or shrub to be tested) of plastic film, each about 3 square feet, to use as shields while spraying.
5. Several available trees and shrubs. Examples: trees (deciduous)—elm, maple, birch, and others; shrubs—privet, pyracantha, azalea, and others; conifers—any species.

Procedure:

NOTE: This experiment can be either a long or a short-range project. By making it a long-range project you can conduct tests during the fall, winter, and spring. This will enable you—the researcher—to determine the proper time of year for applying chemical pruners. If a short-range project is desired, start about March 1 and test every other week for six weeks. In more northern areas, April 1 will be a more satisfactory starting time.

1. After receiving the pruning agent from the manufacturer, mix various concentrations for use in your test. If you try a 3-percent, 4-percent, and a 5-percent concentration you may be able to determine the proper dosage for different species.
2. In your home yard or on the school grounds, select trees or shrubs that you have decided to test for chemical pruning. (See general precautions on page 3 which should be observed in applying pesticides.) Select a control branch from the same tree or shrub for each branch you are testing. Remember that you are going to spray the tip of the selected branches.
3. Tag each branch that you have selected with the following information:

	(Example)
Name of plant:	Privet
Concentration:	2 percent
Date:	May 5, 1971
Time:	2:30 p.m.
Temperature:	(If desired)

   Record the same information in a date book and leave enough space to describe the reaction of the plants to the chemical pruner. Tag and test as many different species of plants as possible.
4. Preparing the shields: Use sheets of plastic film to protect the rest of the tree or shrub when you are spraying the branch tips that you have decided to test. One sheet should have a slit so you can slip the sheet over the branch between the area to be sprayed and the remainder of the branch. Place the other sheet below the branch to be sprayed.
5. After placing the shields on the tree or shrub, you are ready to spray the branch tips. Using the atomizer or similar device, spray the leaves and twigs in front of the shield with a fine mist. Be sure to wet them to the point of runoff. Remember to

treat at least several branches on each tree or shrub. Treat at least one plant in each group: deciduous trees, shrubs, and conifers. Mark control branches but do not spray them.

6. Watch for reaction in an offshoot of a twig. The first sign will be the blackening of the newest leaf on the twig. Later this black portion will dry and turn brown. Reactions will start in as early as one hour with some plants and as late as one day or more with other plants. It is quite possible that some species will not react at all. Record all reactions in your data book.

Observations:

1. Compare the reactions of the three plant groups: deciduous trees, shrubs, and conifers.
   a. What group reacted most?
   b. What group reacted least?
   c. Did any group fail to react?
   d. What species reacted most?
   e. What species reacted fastest?
   f. What species reacted slowest?
2. Compare the different concentrations.
   a. What concentration worked best?
   b. What concentration worked least?

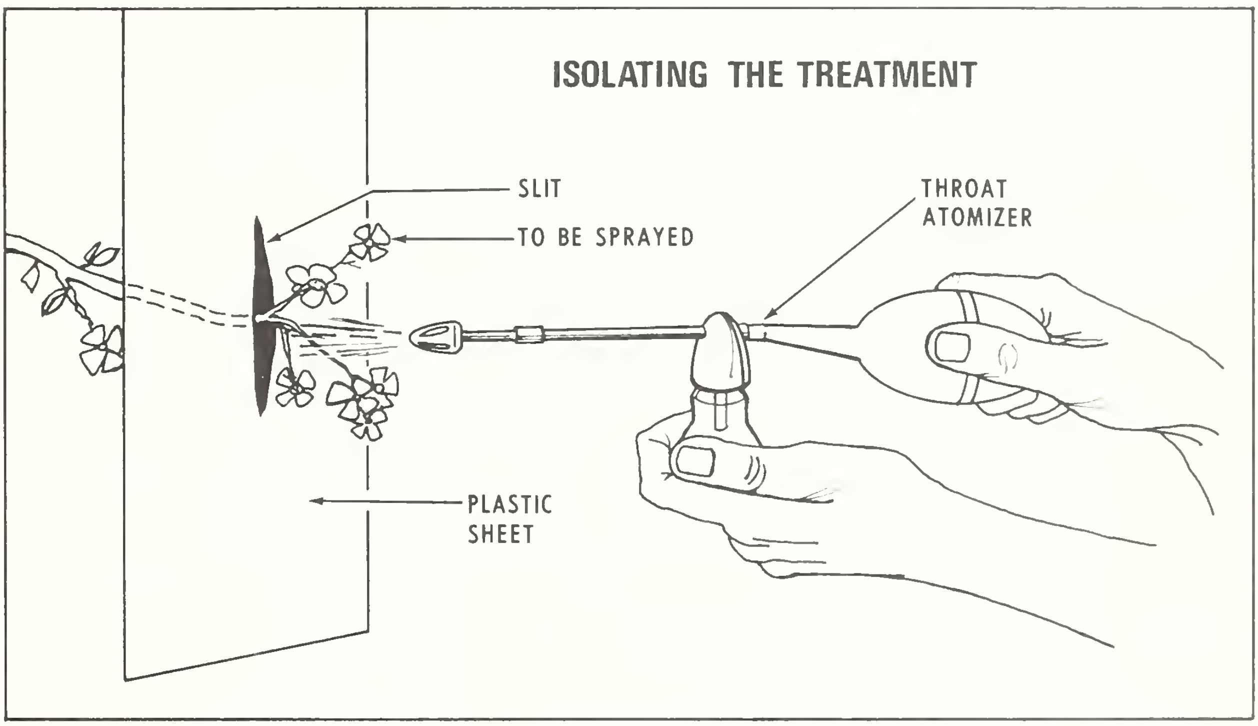

Figure 5 - Plastic film sheets are used to protect the rest of the tree when spraying the branch tips.

EXPERIMENT VII:
Chemical Pruning of Coleus and Ivy

An exciting new possibility in plant control is now in the experimental stage of development by the U.S. Department of Agriculture, at the Agricultural Research Center, Beltsville, Md. In this project, scientists are attempting to develop reliable compounds to chemically prune plants. Many plants, especially in commercial greenhouses, require time-consuming and expensive hand pruning or pinching to develop the desired product.

Horticultural scientists have developed and experimented with several promising compounds. One of the most promising is a derivative of fatty acids. The following experiment is a basic example of how the scientists have been testing fatty acid emulsions for selective pruning. This project is still in the experimental stage and extensive research is being conducted to insure positive results.

Objective:

To test the selective action of chemical pruning agents on house plants by comparing the development of treated and untreated plants.

Materials:

1. Potted plants.
   a. Potted coleus with tissue of various ages (an old plant).
   b. Potted ivy with tissue of various ages.
   c. Bean seedlings that are 7 to 10 days old (start plants so they are the the right age at the time of application).

NOTE: For each test plant select a control plant of equal size and age.

2. A 1-quart hand-sprayer or a throat atomizerer.
3. Chemical pruning agent.
4. Growth-regulating compounds can be obtained from companies listed on page
5. A proper place to keep and spray your test plants as well as your control plants.

Procedure:

1. Select your plants so that you have a test plant and a control for each treatment. You may test as many plants as you like, depending upon what is available.
2. Tag each plant with a waterproof tag so that it can be marked and identified during and after treatment.
3. Select a warm, well-lighted place to keep your plants during the experiment. It is best to have two separate places, identical in climate, one for your test plants and one for the control plants. This will prevent accidental spraying of the control plants.
4. Prepare the pruning agent. (Precaution: Do not inhale mist when spraying. In case of contact with face or eyes, wash with water. Keep chemical and spray apparatus out of the reach of small children and others not involved in the experiment.)

5. Dilution Chart

Dosage level—fluid ounces of chemical per quart of emulsion	5.4	4	3.6	2.9	2.5	2.1	2	1.7	1.5
Dilution ratio	1:4	1:7	1:8	1:10	1:12	1:14	1:15	1:18	1:20

   a. Select a dosage level from the dilution chart.
   b. Measure the required amount of the compound you are using into a clean quart container.
   c. Slowly add an equivalent volume of water and stir or mix into a uniform emulsion.
   d. While stirring, slowly add more water to fill the quart container. Shake well. This will be the emulsion with which you will spray your

test plants. Dosage: The more plants that you have, and the more different concentrations that you experiment with, the more interesting your experiment will be.

6. Spray the plants.
   a. One spraying should be all that is necessary to produce effective reaction. Spray only the test plants.
   b. Soil should be wetted before spraying, but the foliage should be dry.
   c. Avoid using any other chemical sprays 48 hours before and after application.
   d. Best results are obtained with a fine spray, but care should be taken to wet each growing tip to the point of runoff.
   e. Ten to fifteen minutes after spraying, rinse the entire plant with water to prevent damage from an overdose. Be careful to prevent the washed off pesticide from going on to the soil in the pot.
   f. Room temperature during application should be 70° to 80° F. Never spray the beans, ivy, and coleus that are tagged as control plants. Remember that the beans must be young seedlings.

Observations:

About one hour after spraying, compare the test plants and the control plants.

1. What has happened to the coleus and ivy that were treated with the emulsion? Why didn't this happen to the entire plant?
2. What happened to the bean seedlings? What is the difference between the beans and the other test plants?
3. What tissue was affected in all plants, young or old?
4. What use can this experiment be to plant growers?
5. To continue the experiment, allow the plants to return to their normal life and care for them as usual. Observe how each plant grows as compared to the control plants.

BIBLIOGRAPHY

Free single copies of the following publication are available from the Publications Division, Office of Information, U.S. Department of Agriculture, Washington, D.C. 20250. Please use your ZIP code with your return address when you order:

Plant Hormones and Growth-Regulating Substances - Agricultural Handbook No. 336.

The following Government publications are for sale only. Send order together with remittance to the Superintendent of Documents, Government Printing Office, Washington, D.C. 20402. Remittances can be made by coupons which are sold by the Superintendent of Documents in the denomination of 5 cents, postal money order, express order, or personal check. Currency may be sent at sender's risk.

Using Phenoxy Herbicides Effectively - Farmers' Bulletin No. 2183. 20 cents.

Lawn Weed Control With Herbicides - Home and Garden Bulletin No. 123. 15 cents.

The following publications may be of interest:

"Present Status and Future of Plant Regulating Substances," *Agricultural Science Review,* vol. 4, Fourth Quarter, 1966.

"Chemical Pruning of Plants,," *Science* 153: 1382-1383.

"Growth-Regulating Substances as Herbicides," *The Botanical Gazette,* vol. 108, No. 2, 1957.

The following U.S. Department of Agriculture films may be borrowed from film libraries at land-grant universities in the 50 States, the District of Columbia, and the Territory of Puerto Rico.

"Pests or Plenty"

"Chemicals and Compact Plants"

"Evaluating Herbicides"

SOURCES OF HERBICIDES AND GROWTH REGULATING COMPOUNDS

General growth-regulating compounds

Matheson Scientific of Maryland, Inc.
19727 Tucker St.
Beltsville, Md. 20705

Nutritional Biochemicals Corp.
26201 Miles Rd.
Cleveland, Ohio 44128

Sargent-Welch Scientific Co.
7300 N. Linder Rd.
Skokie, Ill. 60076

Stansi-Scientific
Div. of Fisher Sci. Co.
1231 North Monroe St.
Chicago, Ill. 60622

Curtin Scientific Company
4220 Jefferson Ave.
Houston, Tex. 77023

1234 Parklawn Drive
Rockville, Md. 20852

Distillation Product Industries
Div. of Eastman Kodak Co.
Rochester, N. Y. 14603

Velsical Chemical Corp.
Research Dept.
330 Grand Ave.
Chicago, Ill. 60611

Will Corp. of Maryland
Box 5195
Baltimore, Md. 21224

Herbicide compounds

atrazine
Geigy Chemical Corporation
Ardsley, N. Y. 10502

diuron
E. I. du Pont de Nemours & Company
Wilmington, Del. 19898

molinate
Stauffer Chemical Company
P.O. Box 760
Mountain View, Calif. 94040

trifluralin
Elanco Division
Eli Lilly and Company
Greenfield Laboratories
Box 708
Greenfield, Ind. 46140

Gibberellic acid

Aldrich Chemical Co.
940 West St. Paul Ave.
Milwaukee, Wisc. 53233

2098 Pike St.
San Leandro, Calif. 94577

10 Ridgedale Ave.
Cedar Knolls, N. J. 07927

Sigma Chemical Co.
3500 DeKalb St.
St. Louis, Mo. 63118

Amo-1618

Calbiochem
P. O. Box 54282
Los Angeles, Calif. 90054

E. C. Geiger
Harleyville, Pa. 19438

Polyscience, Inc.
Paul Valley Industrial Park
Warrington, Pa. 18976

Tissue cultures and reagents

Grand Island Biological Co.
3175 Staley Rd.
P. O. Box 68
Grand Island, N. Y. 14072

Radiochemicals, growth regulators and related compounds, tissue culture media:

Schwartz-Mann BioResearch
Div. of Becton, Dickinson & Co.
Mountain View Ave.
Orangeburg, N. Y. 10962

Chemical pruning agents

Emery Industries, Inc.
4300 Carew Towers
Cincinnati, Ohio 45202

Proctor & Gamble
Agricultural Chemical Section
AS & CPD, Proctor & Gamble Co.
Ivorydale Technical Center
Cincinnati, Ohio 45217

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Agricultural Research Service

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